HOW TO

INSPECT, REPAIR, TEST, CALIBRATE, READ and COMPUTE

Electric, Recording,

AND

Integrating Meters,

BY

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Warren County Printing Co.

THOMSON

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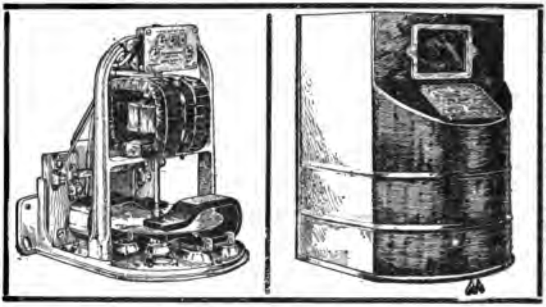

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PREFACE.

In presenting this little book to the "fraternity" it may be that some apologies should go with it. In 1897 after having tired of traveling, the writer made up his mind that to be successful it was necessary to become "efficient." I discovered I was not. I had a general experience, but I could not find a general job. What was wanted was men with special experiences. I adopted a specialty, it was meters. I accepted what was offered to go into a factory and get a training that would fit me to take charge of a meter department in a large station. After remaining there six months it was my good fortune to find a place with a large station, but I discovered again that what I learned in the factory only applied in part to what I was expected to know now. For instance (it may sound queer) in the factory I was taught all about meters except how to read one. You can go into any factory where they make meters today and you will find men actually capable of testing and calibrating, but who could not read a meter. My value to that station was in proportion to the meters they had that I knew about, was to the total number of meters they had of all makes, so possibly I was too much of a specialty. There were some things I learned in the factory that I had to forget. There were things I needed to know that I did not get at the factory. In other words there is a big difference between factory accuracy and commercial usefulness. During all this time I thought of the many who though capable did not have the opportunity that I had, and who if they did have they probably couldn't afford to sacrifice the salary they were getting to accept what would be offered to learn the meter business. So I made notes; I studied the requirements of the men who have the care of meters; I compiled my notes, and this little book is the result. It is dedicated to the men who handle the pliers.

THE AUTHOR.

PART ONE.

1. ANY MAN of the average intelligence can become an expert meter man. Of course a technical education is desirable but the writer contends that it is not necessary. Some things however are necessary, and it is the object of this little book to explain them in as few plain every day terms and phrases as possible. By this is meant in the language of the practical electrician.

2. THE FIRST THING TO DO is to find out what it is we want to know; next is to find out how to go about it. When we discover that we want to know how to calibrate a meter we must stop and think of what we must know first; master that, then take the next step, always being sure that we are not attempting to skip anything. The average man forgets a great deal during his life so we will assume that what is first needed is a little drilling in arithmatic.

3. TO SECURE AN INTELLIGENT SOLUTION of arithmetical problems for use in meter work one must become familiar with the generalization of Intergers, Common Fractious, Decimal Fractions, Percentage, Involution, Evolution, Ratios and Proportions.

4. THE "SLIDE RULE" too should be studied with appreciation of the amount of labor that can be saved by its use, for the reason that with it, results can be obtained while one would be putting down the initial figures in the "paper and pencil" method of calculating.

5. CALCULATING SLIDE RULES can be purchased anywhere and a book of instructions go with them. It would do no good to explain the "Rule" here, besides the book on the "Rule" cannot be improved upon. The book may be dry reading at first but it will be time well spent.

6. BESIDES THE ABOVE REQUIREMENTS there are a few more, but we will take a little run

through arithmetic, and later, on the principle that we have forgotten, we will take up the others:

7. SIGNS.

Equality, $=$
Addition, $+$
Multiplication, $\times$
Subtraction, $-$
Division, $\div$
Percent, %
To be Squared, 2^2
To be Cubed, 3^3
Square Root, $\sqrt{}$
Cube Root, $\sqrt[3]{}$
Ratio. :
Proportion, :: or $=$
Degree, °

8. THE VALUE OF SIGNS in arithmetic should be thoroughly appreciated. The student should learn to use them exclusively.

9. ADDITION: Only like numbers and like orders can be added. The sum expresses units of the same kind as its addends.

10. SUBTRACTION: Only like numbers and like orders can be subtracted, one from the other The remainder or difference expresses units of the same name, as those expressed by the minuend and subtrahend. The increase of any order in the subtrahend is equivalent to a corresponding decrease of the same order of the minuend.

11. MULTIPLICATION: Is a short process of finding the sum when the several addends are equal.

12 DIVISION: Is the process of finding one factor when the product and the remaining factors are given

13. A DECIMEL FRACTION expresses one or more of the equal decimal parts of a unit. The nearer any figure of a decimal fraction is to its decimal point,

the higher its value; the further it is removed from the decimal point, the less its value.

14. A COMMON FRACTION expresses one or more of the equal parts of a unit. One of the equal parts is called a fractional unit.

NUMERATOR denotes figures above the line.

DENOMINATOR denotes figures below the line.

15. ADDING FRACTIONS: Rule. Reduce to equivalent fractions of a common denominator, add the resulting numerators, and place the sum over the common denominator.

16. SUBTRACTING FRACTIONS: Rule. Reduce to equivalent fractions of a common denominator, and place the difference between the resulting numerators over the common denominator.

17. TO ADD OR SUBTRACT MIXED NUMBERS: Add or subtract the fractions and intergers separately, and combine the results.

18. MULTIPLICATION OF FRACTIONS: Multiplying is to increase; to do so multiply the numerator or divide the denominator.

19. DIVIDING FRACTIONS is to decrease their value. To do so divide the numerator or multiply the denominator.

20. MULTIPLYING OR DIVIDING both terms of a fraction does not change its value.

21. TO MULTIPLY MIXED NUMBERS: Rule. Whole number $\times$ whole number. Upper digit $\times$ lower fraction. Lower digit $\times$ upper fraction. Fraction $\times$ fraction. Product of all added together.

22. DIVISION OF FRACTIONS: Inverting any number simply demonstrates the number of times it is contained in a unit, as the unit takes the place of the numerator so must the number take the place of the unit. Divide 6 by 7; answer, $\frac{6}{7}$. By inverting the divisor we find $\frac{7}{1}$, $\frac{1}{7}$. If 7 is contained in one unit $\frac{1}{7}$ of one time it is contained in 6 six times $\frac{1}{7}$, or $\frac{6}{7}$. Divide 5 by

$\frac{4}{5}$. Ans. $6\frac{1}{4}$. $\frac{4}{5}$ is contained in a unit $\frac{5}{4}$ times, therefore it is contained in $\frac{5}{1}$, $\frac{5}{1} \times \frac{5}{4} = \frac{25}{4} = 6\frac{1}{4}$. Ans.

23. TO ASCERTAIN the number of times the divisor is contained in a unit invert the divisor and multiply by the unit in the dividend. Divide 3 by $\frac{4}{7}$. Ans. $5\frac{1}{4}$. Divide $\frac{3}{4}$ of $\frac{2}{5}$ by $\frac{4}{5}$ of $\frac{1}{2}$. Ans. $\frac{3}{4}$. $\frac{3}{4}$ of $\frac{2}{5}$ means $\frac{3}{4} \times \frac{2}{5}$, therefore $(\frac{3}{4} \times \frac{2}{5}) \div (\frac{4}{5} \times \frac{1}{2}) = (\frac{3}{4} \times \frac{2}{5}) \times (\frac{5}{4} \times \frac{2}{1}) = \frac{6}{20} \times \frac{10}{4} = \frac{60}{80} = \frac{3}{4}$.

24. PERCENTAGE. The Base, the number on which the percentage is calculated. The Rate, the number denoting the per cent. The Percentage; the sum (in hundreds) obtained from multiplying the base by the rate. The Amount, the base increased by adding the percentage. The Difference, the base diminished by subtracting the percentage.

25. Base $\times$ Rate $=$ Percentage. (Point off two places from the right.)

Base $+$ Percentage $=$ Amount.

Base $-$ Percentage $=$ Difference.

Percentage $\div$ Base $=$ Rate.

Percentage $\div$ Rate $=$ Base.

Amount $\div$ (1.00 $+$Rate) $=$ Base.

Difference $\div$ (1.00 $-$ Rate) $=$ Base.

To find loss or gain in percent find difference between initial and final values and divide this difference by the initial value.

26. INVOLUTION is the process of multiplying a number by itself one or more times The product thus obtained is called a power of that number. The second power of 2 is 4. $2 \times 2 = 4$. Third power of 2 is 8. $2 \times 2 \times 2 = 8$.

27. THE SMALL FIGURE placed to the right of and a little above a figure is called the Exponent and shows how many times the number is to be used as a factor, or to what power it is to be raised, as $2^2 = 2 \times 2 = 4$. $4^3 = 4 \times 4 \times 4 = 64$.

28. THE ROOT of a number is that number which used the required number of times as a factor produces

the number. 2 is a root of 4 since $2 \times 2 = 4$. 4 is a root of 64 since $4 \times 4 \times 4 = 64$.

29. THE SECOND POWER of a number is called its square. 4^2 should be read 4 squared. The third power of a number is called its cube. 4^3 would be read 4 cubed.

30. EVOLUTION is the reverse of Involution. It is the process of finding the root of a number that is considered as a power.

31. THE SQUARE ROOT of a number is that number when used twice as a factor produces that number 3 is the square root of 9 since $3 \times 3 = 9$, or $\sqrt{9} = 3$.

32. THE CUBE ROOT of a number is that number which if used three times as a factor produces that number. 3 is the cube root of 27 since $3 \times 3 \times 3 = 27$, or $\sqrt[3]{27} = 3$.

33. THE RADICAL SIGN ($\sqrt{\ }$) placed before a number, indicates that some root of that number is to be found

34. THE INDEX of a root is a small figure placed over and to the left of the radical sign to show what root is to be found. Thus $\sqrt{50}$ means that the square root of 50 is to be found. Again, $\sqrt[3]{150}$ means that the cube root of 150 is to be found. (When no index is used the square root is to be found.)

35 THE STUDY of Involution and Evolution is one of necessity. The writer recommends that the student who is not familiar with it can best get results by securing the services of one who does understand it and can teach another. After being thus taught learn to use the "slide rule"

36. RATIO AND PROPORTION: Ratio is the relation of one quantity to another of the same kind, or it is the quotient obtained by dividing one quantity by another of the same kind. Two dots (:) means is to, indicate ratio. 8 : 4 means 8 is to 4. The two quantities compared are the terms of the ratio. First is the antecedent; second is the consequent; two terms collect-

ively are called a couplet. The antecedent is a dividend and the consequent is a divisor.

37. AN INVERSE or Reciprocal Ratio is a ratio inverted. That is, the antecedent becomes the consequent and the consequent becomes the antecedent Thus the inverse ratio of $4:9$ is $9:4$.

38. WHEN THERE is but one Antecedent and one Consequent the ratio is simple. Thus $15:5=3$. When the corresponding terms of two or more simple ratios are multiplied together the resulting ratio is compound. Thus $6:3=2$, $8:4=2$, $10:5=2$. Multiplying the above simple ratios we have $6\times 8\times 10:3\times 4\times 5=8$.

39. THE RATIO of 15 feet to 5 feet means the relative value of 15 feet as compared with 5 feet, and is found by dividing the first by the last quantity. Thus $15\div 5=3$.

40. PROPORTION is an equality of Ratio. Thus $8:6=4:3$

41. THE EQUALITY of two Ratios is indicated by the sign $=$, or by the four dots $::$. Thus $12:3=8:2$, or 12 is to 3 as 8 is to 2.

42 THE FIRST and last terms of a proportion are called extremes. The second and third, means. If the means are the same number then this number is called a mean proportional. Thus $9:6=6:4$, 6 is a mean proportional between 9 and 4.

43. IN A PROPORTION the product of the extremes is equal to the product of the means. For a proportion $3:4=6:8$ may be written $\frac{3}{4}=\frac{6}{8}$. Reducing the fractions to a common denominator we have $\frac{3\times 8}{32}=\frac{6\times 4}{32}$. (Note first and last extremes, second and third means) $3\times 8=6\times 4$, 3 and 8 extremes, 6 and 4 means. It follows that either extreme is equal to the product of the means divided by the other extreme, and either mean is equal to the product of the extremes divided by the other mean. That is, if any three terms of a proportion are given, the other can be found.

44. A MEAN PROPORTION between two numbers is equal to the square root of their product.

45. WHEN MORE requires more, or less requires less the proportion is called direct. When more requires less or less requires more, the proportion is called inverse.

46. TO SOLVE EXAMPLES by proportion, make the number that is the same kind as the required answer, the third term. If from the nature of the example the answer ought to be greater than this third term, of the two remaining terms make the greater the second and the lesser the first, but if the answer ought to be less than the third term, make the lesser the second and the greater the first.

47. A FORMULA is an abridged statement of a general rule, in which symbols are used. The symbols used are letters of the alphabet which represent numbers and the signs have the same meaning as in arithmatic. $C = \frac{E}{R}$ is a formula and means that each letter has a value. The value of E is to be divided by the value of R and the quotient will be the value of C.

48. REMEMBER A FORMULA IS SIMPLY A RULE. The sign ($+$) means addition and is called plus. The sign ($-$) means subtraction, and is called minus. The sign ($\times$) means multiplication, and is read, times. The sign ($\div$) means division, and reads divided by. The sign ($\sqrt{}$) means that some root of the quantity to the right is to be taken, and is called the radical sign.

49. THERE ARE FOUR SIGNS OF AGGREGATION as follows: (——) The Vinculum. (   ) The Parenthesis. [   ] The Brackets. {   } The Brace.

50. THE TERM AGGREGATION MEANS COLLECTION.

PART TWO.

1. A SHORT RUN through the primary of Electricity will now be in order. We will leave out all history and consider only such terms, phrases and rules that are necessary to know. If the student finds that there are other things he wants to know about Electricity the writer recommends that he procure books that deal particularly on the subject

2. VOLT AND AMPERE METERS: Indicating Watt Meters and Dynamometers need hardly be elaborated on here for we assume that any one who knows the least about a station knows what these instruments are and what their value is. Again, the writer will state that he has obtained much practical information from catalogues of the manufacturers.

3. AMPERE: Unit of current strength. The flow of electricity produced by the pressure of one volt on a resistance of one ohm.

4. OHM: Unit of electric resistance. It is equal to the resistance of a prism or pure mercury of one square millimeter section and 1.0486 meters long at 32° F.

5. VOLT: Unit of pressure. (E. M. F.) Analogous to the head of water in hydraulics. The pressure required to drive one ampere through one ohm resistance.

6. WATT: Unit of work. $\frac{1}{746}$ H. P.

WATTS = amperes squared $\times$ ohms resistance.

WATTS = amperes $\times$ volts.

WATTS = volts squared $\div$ ohms resistance.

7 KILO WATT = 1000 watts.

8. E. M. F. Electro-motive Force = ampheres $\times$ ohms.

9. RESISTANCE: Ohm = volts $\div$ amperes.

10. CURRENT: Ampere = volts $\div$ ohms.

11. THE STRENGTH OF A CURRENT in amperes varies directly as the E. M. F. applied to produce it, and inversely as the resistance of the circuit.

12. JOINT RESISTANCE OF BRANCH CIRCUITS: The resistance of a conductor is directly proportional to its length, and inversely proportional to its cross section. The conductivity of a wire is the reciprocal of its resistance. Thus, if a wire has a resistance of one ohm its conductivity is 1. When the resistance is two ohms the conductivity is $\frac{1}{2}$. When the resistance is three ohms the conductivity is $\frac{1}{3}$. When the resistance is $\frac{4}{5}$ the conductivity is $\frac{5}{4}$, and so on. (The reciprocal of a number is one divided by that number).

13. TO FIND THE JOINT RESISTANCE OF A DIVIDED CIRCUIT find the sum of the conductivities of the different roads open to the current; the joint resistance will be the reciprocal of the results thus obtained. Example: Find the joint resistance of two wires offering 3 ohms and 7 ohms. Joint conductivity $= \frac{1}{3} + \frac{1}{7} = \frac{7+3}{21} = \frac{10}{21}$. Joint resistance $= \frac{21}{10} = 2\frac{1}{10}$ ohms.

14. DIVISION OF CURRENT IN BRANCH CIRCUITS. The relative strength of a current in the different branches of a divided circuit will be inversely proportional to their resistance; the conductivities being reciprocals of each other. See Fig. No. 1. Current going from A to B through C and D, if each offer equal resistance the current will divide equally, but if C offers 19 ohms and D offers 1 ohm and we consider that the current consists of 20 parts, $\frac{19}{20}$ will go through D and $\frac{1}{20}$ will go through C.

15. STRENGTH OF CURRENT.

$$C = \frac{E}{R} = \text{Amperes.}$$

$$R = \frac{E}{C} = \text{Ohms.}$$

$$E = C \times R = \text{Volts.}$$

16. THE E. M. F. OF A CELL is one volt and its internal resistance is 2.8 ohms. Find the strength of

current when the internal resistance is 5 ohms. $C = \frac{E}{R} = \frac{1}{2.8+5} = \frac{1}{7.8} = .128$ Amperes.

17. HORSE POWER, a commercial unit for power or rate of doing work, a rate of doing work equal to 33,000 pounds raised one foot per minute, or 550 pounds one foot per second.

18. A CAREFUL DISTINCTION must be drawn between work and power. The same amount of work is done in raising 1 lb. through 10 feet, whether it is done in one minute or one hour. The power expended or the ratio of doing work is, however, quite different, being in the former case sixty (60) times greater than in the latter.

19. 1 H. P. = 550 ft. lbs. per second.

20. 1 H P. = 33000 ft. lbs. per minute.

21. 1 H. P. = 745.941 watts (practically 746).

22. CANDLE POWER. "Candle" is the unit of photometric intensity; it is such a light as would be produced by the consumption of two grains of a standard candle per minute. An electric lamp 16 candle power, or one 2000 c. p., is a light that gives respectively 16 or 2000 times as much as one standard candle.

.23. CANDLE FOOT, 1 c. p at a distance of one foot.

24. CANDLE METER, 1 standard candle at a distance of one meter.

25. TO COMPARE THE POWER OF TWO LIGHTS an instrument called a Photometer must be used.

26. TO FIND THE C. P. OF A LAMP it must be compared with another, the candle power of which is known.

27. A PHOTOMETER in its simplest form consists of a white paper screen, which can be moved along a graduated scale, at the ends of which the two lamps to be compared are placed. A spot of grease is made in the center of the screen which is moved on the scale un-

til the point is found at which the grease spot cannot be distinguished from the other portion of the screen, this being an indication that illumination on each side of the screen is equal. The distance from the screen to each light is noted by the scale, and the proportion of the illuminating power of one light to the other will be inversely as the square of the distance from the screen.

28. APPLY to manufacturers of Inc. Lamps and Photometers for general information on testing lamps.

29. A DYNAMO ELECTRIC MACHINE is a machine for converting mechanical energy into electrical energy. It generates electric current when driven by mechanical power.

30. AN ELECTRIC MOTOR is a machine for converting electrical energy into mechanical energy. It produces mechanical power when supplied with an electric current. The dynamo is based upon the discovery made by Faraday in 1831, an electric current is generated in a conductor by moving the conductor in a magnetic field. The motor works on the principal that a conductor carrying a current in a magnetic field tends to move. The dynamo and the motor are exactly the reverse of each other in action.

31. ARMATURES. Direct current machines have armatures with commutators. Alternating current machines have armatures with collecting rings. There are the following kinds of armatures:

MECHANICALLY: spherical, drum, and ring.

ELECTRICALLY: open coil and closed coil.

By right or left hand armatures is meant the relative position of the commutator to coils.

32. IN ALL GENERATORS the currents being set up by the E. M. F are in the same direction as those that impel them. But in motors the currents are being set up by superior E M F. from outside and the induced E. M. F. in the motor armature is always in opposite direction to that of the current that is flowing.

33. ACTION OF COMMUTATION. (DYNAMO). Theoretically the neutral points would be in the vertical line coinciding with that of the gap between the poles. But the neutral line or the diameter of commutation is displaced in the direction of the rotation of the armature. Thus the displacement of brushes to find actual neutral point. The cause of the lead is the reaction that occurs between the magnetic poles of the fixed magnets and those of the armature, the result which is to displace the field magnet poles and to change the density of the field.

34. THE LEADING "SHOE HORN," is that horn of the pole piece which points in the direction of rotation. The diametrically opposite horn is the same; the others are the trailing horns.

35. DYNAMO TRAILING HORN is the point of greatest saturation.

36 MOTOR LEADING HORN is point of greatest saturation.

37. A MOTOR OF 500 VOLTS RUNNING AT FULL SPEED will have a counter E. M. F. of very near the same amount. When an armature is at rest the ohms resistance is very low, usually less than one ohm. It is the counter E. M. F. that offers resistance to the flow of current when the armature is in motion.

38. TO CHANGE DIRECTION OF ROTATION OF ARMATURE in motors, change the direction of the flow of current in armature only.

39. RESISTANCE COILS FOR TEST PURPOSES. German silver wire is desirable for resistance coils. It does not increase in resistance with heat, copper does. The resistance of copper wire increases $\frac{21}{100}$ % for each °F, and $\frac{4}{10}$ % for each ° Centigrade. To find increase in temperature in °, divide per cent. of increase in resistance by $\frac{4}{10}$ for C., and $\frac{21}{100}$ for F. If resistance is 20 % greater when hot than when cold, the rise in temperature will be 50° F. or 97 2° C. Consider the temperature co-efficient of copper 97 % pure.

40. THE OLD RULE FOR THE SAFE CARRYING CAPACITY OF COPPER WIRE is to allow 1 sq. in. cross section of wire for 1000 amperes when the wire is by itself, and 1 sq. in. cross section for 400 to 500 amperes when the wire is covered or surrounded by other wires. Circular mils (C M) = the diameter (expressed in mils) squared (d^2).

41. THE "WHEATSTONE BRIDGE" SYSTEM OF MEASUREMENT (of resistance) is based upon the fall of tension of the current. See Figure No. 2. Suppose the current to start from Battery and flow to post one Here it divides, ½ passing through the wire A, 3, B. to 2 ; and the rest by C, 4, D, to 2, and thence the current returns to the battery. The resistance of the sides A and C and B and D being alike, the tension of the two portions of the current at 3 and 4 is the same, and no current will pass across from 3 to 4 through the galvanometer. Again, suppose we insert at A, a resistance of 10 ; at B, 100 ; at C, 500 ; and at D, 5000. We find no deflection of needle because the current divides at 1 inversely as the resistance of the two routes, 1, A, 3 ; and 1, C, 4 ; and the resistance at C being 50 times greater than the resistance at A, 50 parts of the current will pass through A with a resistance of 10, while 1 part passed through C with a resistance of 500. The tension of the portions on arriving at 3 and 4, are the same ; and as the same proportion as between A and C, is found between B and D, the divided portions pass on until they join at 2, and return to battery. Therefore, when A bears the same proportion to C that B does to D, or when A : C = B : D, no current will pass between 3 and 4.

42 NOW LET US MEASURE AN UNKNOWN RESISTANCE which we will insert between the binding posts at D. Say we put 10 ohms in at C, and 1 at A, the needle is strongly deflected. Now insert resistance at B until needle comes back to 0, say it requires 250 units, (ohms), then $\frac{10 \times 250}{1} = 2500$, which is the resistance at D.

43. IF THE RESISTANCE TO BE MEASURED is small you may insert equal amounts at A and C, and then the number of ohms, (units resistance) inserted at B will exactly equal D.

44. TO MEASURE RESISTANCE WITH A VOLT METER, using it as a galvanometer. See Figure No. 3.

FIRST note the resistance of the volt meter, (see inside cover of box), then see that the voltage cannot vary, note deflection as in No. 1.

SECOND, place resistance to be measured in series with volt meter, then note deflection as in No. 2. The resistance will be inversely proportional to the deflections. (Voltage).

TO FIND UNKNOWN RESISTANCE, subtract the resistance of the volt meter from the amount as shown in No. 2.

45. THE FALL OF POTENTIAL OVER ANY RESISTANCE is the voltage required to pass or push a given quantity of current through that resistance. Or it is the voltage consumed in passing or pushing the current through.

46. THE TERM "FALL OF POTENTIAL" should not be confused with the rated voltage on the line.

47. REGARDLESS OF THE VOLTAGE ON THE LINE, with a fixed quantity of current the drop or "Fall of Potential," over a fixed resistance remains the same.

48. TO MEASURE CURRENT BY FALL OF POTENTIAL. See Figure No. 4. $C = \frac{E}{R}$

The fall of potential is taken from A to B with a volt meter. The resistance from A to B is known. The current in amperes is found by dividing the fall of potential, (volts), by the known resistance, (ohms).

49. REACTIVE COILS SOME TIMES CALLED DIMMERS, consist of an iron core and one winding, there is also a metallic shield surrounding the winding.

By the changing of the position of this shield the voltage, or current load, is regulated as desired.

50. THE COIL is connected in on one side of the line in series with the load. The coil can only be used on alternating currents.

51. ANOTHER DIMMER KNOWN AS "WATER RESISTANCE" consists of two metallic electroids in a vessel of water arranged so that distance between them can be altered. Use pure water adding a drop or two of sulphuric acid per gallon. Acid lowers the resistance of water.

52. A USEFUL CIRCUIT TO GET VARIOUS POTENTIALS. See Figure No. 5. This consists of placing a Rheostat and 10-50 volt, 16 c. p. lamps in series on a 500 volt circuit. There is a switch to each lamp. These should be "knife" for the reason that only one switch should be in at a time. The "knife" shows at a glance if closed or open.

Note all the lamps burn at any time and the Fall of Potential is taken by closing the switch on the desired number. The Rheostat can then be used to adjust to the correct voltage.

53 TO BUILD LAMP BANK FOR "LOADING," use lamps of highest voltage that will be used (110-115 volt), as the same will answer for low voltage purposes, (50 volts).

Arrange each row in different capacity, such as 8-10-16-20-25-32-50 c. p., and so on. For 500 volts or power purposes arrange in multiple series, care being taken that each series contains lamps of equal voltage.

54 A GOOD FUSE should "blow" at once without waiting to heat after the maximum load is applied.

55 FUSES SHOULD BE PLACED IN CIRCUIT in a verticle position when possible. There is a lead oxide forms on the outside of a fuse wire by exposure to the air, which as a tube seems to strengthen the same, and if in a horizontal position the moulten metal remains inside without breaking the circuit, thus allowing an

increase in capacity But if the fuse is in a vertical position the weight of metal will assist it in breaking

56. SOLUTIONS FOR DIPPING BRASS OR COPPER. See Figure No. 6. Commence at 1, go to 2, and so on, dipping in each as numbered. For vessels use earthen ware

Acids, sulphuric and nitric, equal parts.

Potash, 4 lbs. to 1 gal. water.

Hot water for heating purposes and cold for cleansing purposes, should be kept running.

57. POTASH WILL REMOVE lacquer, varnish and paint. Acid will remove dirt, and brighten. For polishing purposes use "buffer."

58 TESTING FOR CLOSED CIRCUITS IN METER FIELDS. See Figure No. 7. Note—This is a horse-shoe magnet of lam-iron and can only be used on alternating current. It is practically a transformer, 50 or 100 volts can be used on the primary. The winding of the secondary on the magnet should be of the same number of turns as the primary of the magnet. The voltage of both will then be the same. Before placing coil on the horn, note the voltage. If the coil is open the deflection will be constant, if the coil is closed the deflection will change. This is of value in testing for short circuits in fields of meters, where the resistance is too low to be measured otherwise

59. HANGER BOARD FOR METERS. Note—There should be no iron used in the board nor near the meter or instruments. The board should be suspended from a frame or rest directly on pillars. Object, to prevent jarring. A good way is to build the frame upon the instrument bench which should be built on stone or brick pillars

60. TRANSFORMERS. Regardless of the size of wire, the ratio of voltage will be the same as the ratio of turns (windings).

61 THE VOLTAGES OF A TRANSFORMER must be proportional to the windings.

62. EFFICIENCY OF CONVERSION. The ratio between the energy present in any result and the energy expended in producing that result.

63. WHEN TRANSFORMERS ARE CONNECTED TO "BUCK" with unequal load or voltage, the difference between the voltages is all that is obtainable. Thus if 100 volts coming in one direction and 150 volts in the other, 50 volts will be available.

64. REGULATION TEST consists of testing voltage on secondary at no load and from that (at various loads) to full load; also at overload.

65. THE TRUE READING OF LOAD must be taken with watt meter or watt dynamometer. A volt meter and am-meter will not give true watts on inductive load.

66. MAGNETS FOR RETARDATION purposes. Magnets are usually made of the best steel (Norway product). They are first formed, then hardened (gas fire), then magetized, boiled and cooled—the latter process frees them from weak magnetism, which brings them to a point of saturation. They are then "knocked down." This brings them to a point where they are supposed to become permanent. They are then measured and set aside for eight or ter weeks, then measured again. Those that have not lost any strength are used; those that have lost are re-marked and set aside again, and so continued until they become permanent. Hardening steel causes it to retain magnetism. Magnets are magnetized by being placed between two electro magnets with a disc traveling between the poles as placed on a meter, the disc cutting the lines of force. The boiling is done at a point which will cause a difference of about 200° F. between that and the cooling, the latter being done in cold water. The boiling and cooling causes an expansion and contraction, causing the magnet to be freed from loose magnetism.

67. THE MEASURING OF MAGNETS is done by using one of them for a standard and comparing the oth-

ers to it. They are measured in points, (no other name).

68. MAGNETS WILL LOSE THEIR STRENGTH by age, especially if kept near stray currents. Heavy leads, running belts or machines, magnets can be "knocked down" by holding the same in a coil of wire (field coil), conducting a heavy alternating current.

69. THE BRASS SHOES ON MAGNETS should be put on South pole side, thus insuring the North pole being placed on top of disc.

70. SHUNTS VARY IN SIZE, direction of winding, and in number of turns, as well as size of wire used.

71. ASSEMBLING AND REPAIRING. In assembling meters the work is purely mechanical. By knowing the capacity of meter, the Form and Type and efficiency, and consulting the data sheet of manufacturer, one can readily determine the parts proper. The most important point in this work is to reduce the friction of moving parts to a minimum. This is done by getting true lines on the base frame and shaft, caring for the pivot, jewel and top bearing. Almost of equal importance is the truing of the disc on the shaft. Each disc should be trued on the shaft it is intended to be used on. Next of importance is the meshing of gears in the clock, and of clock gears to the spiral screw, or worm thread on shaft. Note that clocks are well cleaned and oiled. Frames and parts can be "dipped" to clean and brighten. To preserve the brightness lacquer can be used.

72. CLOCKS ARE BEST CLEANED by dipping in naptha. First remove face. To clean face, use water. Naptha or alcohol will cut the lacquer used on same.

73. BRUSHES ARE BEST CLEANED with a file. Remove the brushes and use a very fine cut file.

74. COMMUTATORS, IF WORN, should be turned down. Run at very high speed and use a clean cutting tool. Finish with crocus cloth.

75. IN SOLDERING CONNECTIONS OF ARMATURE use soft solder. For a solution use resin and alcohol.

76. FOR INSULATION ON LEADS from resistance cards, etc., do not use rubber tubing; use cotton braid (round), and shellac. The sulphur from rubber will cause corosion, especially on commutator and brushes, when subject to heat.

77. AVOID assembling near where there are filings or turnings from lathe work. Use wrenches and screw drivers that fit, and are in proportion to screws.

78. IN PLACING MAGNETS see that North pole is on top side of disc.

79 THE OIL USED ON CLOCKS AND JEWELS is the best quality of "porpoise," jeweler's oil. Use very little of it.

80 TO REMOVE SHUNTS pass from $\frac{1}{2}$ to 1 ampere of current through same to heat up and melt schellac.

81. CONSIDERING ALTERNATING CURRENT relative to meter work, consider the instantaneous polarity as direct current. The relation of armature to field is the same in both cases.

82 THEORETICALLY AN ALTERNATING CURRENT should give the same results on a motor as does direct current, but in practice with the use of alternating current (single phase) only motors of small capacity ($\frac{1}{4}$ H. P. or less) are self starting.

83. "THREE PHASE" OR "MONOCYCLIC" SYSTEMS obviate this trouble.

84 EFFICIENCY OF DYNAMO $= \frac{\text{Electrical Power.}}{\text{Mechanical Power}}$

85. EFFICIEECY OF MOTOR $= \frac{\text{Mechanical Power}}{\text{Electrical Power.}}$

86. BY EFFICIENCY OF METER is meant the comparative amount of energy it consumes in itself.

87. AN INCREASE IN AMPERE TURNS IN SHUNT will cause meter to speed up on light load. If the increase required is too much it may cause a decrease in speed for the reason that with increased number of turns in shunt, we also increase the resistance of potential path; therefore, for the increase of resistance in

shunt there should be a corresponding decrease in resistance coil.

88. OVER COMPOUNDING is getting wrong combination of resistance, shunt and magnets. If a meter is a certain % slow or fast on light load, the same % decrease or increase (as required) of number of turns in shunt, will give required speed.

89. ON HEAVY LOAD, IF SLOW OR FAST, A CERTAIN %, the same % increase or decrease of magnet strength (as required) will give the proper speed.

90. DISC. When a meter is a certain % slow or fast, the same % increase or decrease (as required) in thickness of disc will give required speed.

91. TO TEST LIFE OF JEWEL. Take magnets off meter and let run at high speed. Clock will register watt hours. From this compute number of hours at any speed.

92. A SHORT CIRCUIT ON LINE WHEN METER IS IN USE will "knock down" the magnet strength, thus allowing meter to speed up. This is due to magnetic circuit being increased in size so that magnets come within its range.

93. WHEN INSTRUMENTS CALIBRATE LOW OR HIGH. When measuring with volt or ampere meter for watts, and the instruments are low, add the rate percent low of each instrument together. After finding the product of the deflections, find the correct amount by multiplying that product by the rate low + 1.00.

EXAMPLE: Let the am-meter read 25 and the volt meter read 500, the am-meter is 1 per cent low, the volt meter is $1\frac{1}{2}$ per cent low; $1+1\frac{1}{2}=2\frac{1}{2}$, $25\times500=12500$, which is $2\frac{1}{2}$ per cent lower than correct reading should be. Correct reading is $12500\times1.025=12802.5$.

94 WHEN INSTRUMENTS READ HIGH, add the rate % high of each instrument together. After finding the product of the deflections, multiply the same by 1.00 less the rate high.

EXAMPLE. Let the am-meter read 25 and the volt

meter 500, and the combination 2½ % high; 25×500= 12500, which is 2½ higher than should be, or it is 102½ % of what the reading should be. The correct reading is 12500×97½=12187.5.

95. SHOULD ONE INSTRUMENT BE HIGH AND THE OTHER LOW, find the difference between the two and note if the result shows the combination to be correct, high or low. Let the am-meter be 2½ % high and the volt meter 2½ % low, the combination is correct. Let the volt meter be 2½ % low and the am-meter 3½ % high, the combination is 1 % high. Proceed as directed above.

96. TO FIND IF AM-METERS OR VOLT METERS ARE CORRECT, compare them with standard instruments. If found to be correct, high or low, they should be so marked and dated. The marking should be indicated in %.

97. CALIBRATING. Connect up meter and allow same to heat one-half hour before testing. Object—with increase of heat in potential path, meter will slow down, test when at maximum heat. Test on full load, no load, light load, again on full load, light load and no load.

98. A METER PROPERLY TESTED should be calibrated by one person with one set of instruments, and "checked" by another with another set of instruments. Two persons are less liable to make the same mistake, than one person is to make the same mistake twice.

99. IF TESTING WITH A WATT DYNAMOMETER OR INDICATING WATT METER, consider the current coil as an am-meter, and the potential coil as the volt meter. Use only a watt dynamometer, or direct reading indicating watt meter, to test meters on inductive load. Am-meter and volt meter, (separate) will not give true reading in watts or inductive load. Then always put am-meter in circuit on load side of meter and the volt meter across the mains on machine side of and as near the meter as possible. Object: we do not want to measure the current in the potential path, nor do we

want to consider the drop over the fields.

100. The customer should pay the field loss, and the station stand the potential loss, as in the above case.

101. THE FIELD LOSS is found by $C^2 \times R =$ watt loss. The potential loss can be found by $C \times V =$ watt loss. To prove that the field loss is paid for by the customer, find what % of the rated capacity (in watts) of the meter the field loss is, then take the fall of potential over the fields and the % that is to the rated voltage will equal (very near) the % the field loss is to the rated capacity of the meter, in watts. If we put the am-meter on the machine side we would measure the potential current; if we put the volt meter on the load side, we would get the correct voltage less the drop over the field.

102. ALL INSTRUMENTS USED should be kept at least one foot apart. Object; they will if, near enough, influence each other. They should be kept free from jar or vibration and excessive heat or cold.

103. METERS SHOULD BE SUSPENDED AND FREE FROM JAR OR VIBRATION. Meters with iron frames or parts are for use on alternating current only.

104. FULL LOAD need not be rated capacity of meter.

105. LIGHT LOAD equals 5% of rated capacity of meter. Meters of small capacity where 5% of same is less than one-half ampere, can be tested on any specified load. "No load" is potential circuit only.

106. THE CLOCK METHOD OF TESTING METERS SHOULD NOT BE CONSIDERED.

107. IN CALIBRATING WITH AMPERE AND VOLT METER. Amperes $\times$ Voltage $=$ Instrument Watts.

With Watt Dynamometer, deflection $\times$ K $=$ Instrument watts.

$$\frac{\text{Recorded watts}}{\text{Instrument watts}} = \text{Ratio.}$$

108. IF THE INSTRUMENT WATTS are more than the recorded watts the meter is slow, if less the meter is fast.

109. TO FIND PERCENT SLOW OR FAST find the difference between the instrument and recorded watts, divide this difference by the instrument watts.

110 TESTING BY STANDARDS (meters) is only practical in factories. It consists of placing two meters side by side and noting if the run in synchronism. At best this method can be used only on heavy load.

111 ALL WATT METERS are accurate within a considerable range of voltage, and the potential given is only the average. In testing meters regardless of the above, the voltage should be maintained within less than 5 % of the rated voltage of the meter.

112. MORE THAN ONE METER can be tested or connected (fields in series) together, care being taken that one meter does not measure the potential current of the others.

113. METERS ARE USUALLY CALIBRATED 5 % SLOW ON LIGHT LOAD. This is to insure against running on no load.

114. TIMING METERS WITH A STOP WATCH. The longer you let a meter run (on timing it) in calibrating, the less chance for error. Thus if you read 50 revolutions in 51 seconds, you would be liable to read it on 10 revolutions 10 seconds, where it should be $10\frac{1}{5}$ seconds. To avoid mistakes in taking different readings, time on different number of revolutions.

115. ALL METERS HAVE A "K." Meters that are direct reading have a K-1. If the K was O and we multiplied the reading by O, we would have O for an answer. (K = Constant.)

116 THE SPEED OF A METER should be directly proportional to the load passing through it.

117. MANY COMBINATIONS can be worked to effect saving of time in testing meters, but unless one is well versed the writer recommends that all testing be

done by conforming as near as possible to the condition, the meter will be subject to in service.

118. THE 3-WIRE SYSTEM is best understood when we consider it the same as two 2-wire circuits. Note—in 3-wire meters, one circuit passes through one field and the other circuit passes through the other field. To get true instrument watts open neutral between meter and load, use one am-meter and take voltage across two outsides. Before opening the neutral see that system is well balanced. This is done when there is no flashing in the lights on snapping the neutral switch. If the neutral is closed it will be necessary to use two am-meters. The sum of the two × voltage of one side (100 volts) will be the true instrument watts.

119. A 3-WIRE METER WITH FIELDS IN SERIES is practically a 2-wire meter. If we consider that a 3-wire 200 volt meter has a K 2, we would then consider it a 2-wire 100 volt meter with a K 1. Reason—in both cases the field strength and speed of meter is the same, the difference is in the instrument watts or load. Connected 3-wire the fields are in multiple, one-half current in each field, we then consider the voltage across the outside. Connected 2-wire the fields are in series, the same current in each field, we then consider the voltage of one side only.

120. 3 WIRE METERS SHOULD BE TESTED on each field separately: there should be no difference between them, nor should there be any difference between poles. In some cases 3 % is allowed and the fastest side of meter is marked positive. This holds good in direct current meters, but makes no difference in alternating current meters.

121. METERS FOR USE ON ALTERNATING CURRENT, where they are tested on direct current, the mean time should be considered. It is best and cheapest, however, to test all meters on the kind of current they are to be used on, except Primary meters. In testing

more than one 3-wire meters together, do so only when it is practical as 2-wire meters.

122. NOTE.—WHEN TESTING EACH FIELD SEPARATELY we get only one-half speed of meter, half the calibrating K, or consider one-half of instrument watts only.

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PART THREE.

THE POINTS TO CONSIDER IN SELECTING A METER are the particular points that we want to be able to test. They are as follows:

Accuracy on non-induction load,
Accuracy on induction load,
Ordinary volt-ampere accuracy,
Accuracy on varying wave forms,
Accuracy on overload,
Accuracy on varying frequencies,
Influence on accuracy of variations of temperature, barometric conditions and humidity.

THE WATT-HOUR AND ITS APPICATION.—A watt-hour is an electrical quantity unit, and indicates a steady consumption of one watt of electrical energy for a period of one hour. In nearly all watt meters, designed to be direct reading, one watt-hour is indicated by one revolution of the meter shaft; in other words, if one watt passed continuously through the meter, the shaft would be one hour making one revolution. If the energy of one incandescent lamp of 16 c. p., or 50 watts, were measured continuously, the meter would register 50 revolutions in one hour, or, since there are 3600 seconds in one hour, each revolution would be completed in $\frac{1}{50}$ of an hour or 72 seconds.

The last statement furnishes a convenient basis from which to work in calibrating recording watt-hour meters having 1 for a constant; it being understood that the time taken for each revolution will be inversely proportional to the watts consumed.

When testing a meter of the class described, it is advantageous to have in mind a simple rule or formula by which to determine the watts consumed. The derivation of such formula is most simple, and is based (in direct reading instruments.) upon the foregoing statement, which, expressed differently, might read each revolution means one watt-hour. If, therefore, the revolutions indi-

cate watt-hours, it is only necessary to divide the watt-hours (or revolutions) by the hours, expressed fractionally, to find the watts consumed in a given time. Take for instance a meter which makes two complete revolutions during a space of 36 seconds; remembering that there are 3600 seconds in one hour, the watts will be, applying the formula,

$$\frac{2}{\frac{1}{100}\text{ (hours)}} \text{ or } \frac{2}{(\frac{36}{3600})} \text{ or } \frac{2\times 3600}{36}=200 \text{ watts.}$$

Supposing a meter having a constant of $\frac{1}{2}$ makes 1200 turns in 3 hours; the watts consumed, will be

$$\frac{1200}{3}\times\frac{1}{2}=200 \text{ watts.}$$

Supposing a meter with a constant 1, makes 3 turns in 15 seconds, the watts consumed would be—

$$\frac{3}{(\frac{15}{3600})} \text{ or } \frac{3\times 3600}{15}=720 \text{ watts.}$$

Hence a uniform consumption of energy, in a given time, we have—

$$\text{Watts}=\frac{\text{Revs}\times 3600\times \text{Constant}}{\text{Seconds}} \text{ or, } W=\frac{R\times 3600\times K}{S}$$

This is the rule most commonly used in meter testing and if the watts, by the formula, correspond to the indicating instrument, the meter is known to be correct If the meter has no constant (or multiplier) the constant (K) may be considered as 1, or may be eliminated, and the equation becomes simply—

$$W=\frac{R\times 3600}{S}$$

NOTE.—Do not try to test a meter by using an ammeter and volt meter, as accurate results are practically impossible; but use instead a PORTABLE INDICATING WATT-METER of recognized accuracy.

It is often desirable to test meters from time to time while they are installed. If a rough test is all that is required it can be made by turning on a specified number of lights, multiplying the number of lights by the watts per lamp to give the load on the meter, and by using the

following standard formula:—

$$\frac{\text{Revolutions}\times 3600\times\text{Constant (if meter has one)}}{\text{Seconds required to make revolutions.}}=\text{Watts}$$

registered by meter.

If a stop watch is used, the only inaccuracy in the test will be the difference between the estimated and the actual watts per lamp.

If a more accurate test is required, a standard wattmeter may be used, such as a portable indicating instrument. By connecting the instrument in series with the meter it will read in watts, and by applying the above formula will give an absolute test.

An accurate test may also be made by the use of a number of lamps whose wattage is absolutely known for different voltages. These lamps can be connected as the only load on the meter, and by reading the voltage of the circuit at the point where the test is made, with a standard portable volt meter, the load in watts may be determined. In this manner a direct comparison may be made.

CALIBRATING FORMULAS, (Thomson Recording Watt Meters)

$$\frac{R\times K\times 3600}{\text{Time}}=\text{Watts.}$$

$$\frac{R\times K\times 3600}{\text{Watts}}=\text{Time.}$$

$$\frac{(W\div 3600)\times\text{Time}}{K}=R.$$

$$\frac{(W\div 3600)\times\text{Time}}{R}=K.$$

"High Potential" Meters tested on "Low Potential."

$$\frac{(R\times K\times 3600)\div\text{Ratio of Trans.}}{\text{Time}}=\text{Watts.}$$

$$\text{Or, }\frac{R\times K\times 3600}{\text{Time}\times\text{Ratio of Trans.}}=\text{Watts.}$$

R=revolutions of disc.

K=constant of meter.

3600=seconds in one hour.

Time=time in seconds (of revolutions).

Ratio of Transformation = Ratio of Voltage of meter (rated) to voltage of potential path.

STANLEY WATT METERS.—A simple formula for determining the wat's in the meter circuit or the accuracy of the meter, if the watts are known, is as follows: (Revolutions×100×constant) divided by (time in second)=Watts. This is similar to the formulas above.

It is given because all the constants that are used in the way described, can be employed. For meters having a constant of 30 the ratio of gearing between the meter shaft and first dial hand is 1 to 1200.

As an example, applying the formula, assume the meter disc to make 240 revolutions in 200 seconds, from the formula the current would be 3600 watts. As the time, 200 seconds, is $\frac{1}{18}$ of an hour, the energy passed in 200 seconds would, of course, be 200 watt hours which is the current that the dial should register during the 200 seconds. Similarly, the revolutions of the disc being 240 and the ratio of the gearing 1 to 1200, the first dial pointer would make $\frac{240}{1200}$ or $\frac{1}{5}$ of a revolution=200 watt hours.

Following is a list of meter constants with total gearing ratios between shaft and first dial hands:

Constants.	Total Ratios.
240	1:150
120	1:300
60	1:600
30	1:1200
15	1:2400

Indicating Watt Meters (Shallenberger). These meters read direct in kilo-watt hours.

To find calibrating K when capacity and speed are known:

$$\text{Amperes} \times \text{volts} = \text{watts, then}$$

$$\frac{(\text{Watts} \div 3600) \times \text{time}}{\text{Revolutions of Disc.}} = K$$

We can omit the K and use a factor which is the product of 3600 times K and the formula for calibration would be: $\frac{\text{Revolution} \times \text{factor}}{\text{Time}} = \text{watts.}$

Another way to find the factor when capacity and speed are known is, note meter makes 50 revolutions in 60 seconds at full load. Find watt capacity at one revolution in one second, and the same will be the factor to calibrate with. To find this, multiply the watt capacity by 60 and divide by 50. Thus:

For a 10 — 100, $10 \times 1000 = 1000$ watts.
50 revolutions in 60 seconds = 1000 watts.
50 revolutions in 1 second = 60000 watts.
1 revolution in 1 second = 1200 watts.

$$\frac{50 \times 1200}{60} = 1000, \quad \text{or} \quad \frac{50 \times 3600 \times \frac{1}{3}}{60}. = 1000.$$

The factors are proportional to the capacity. The corresponding K.s and factors are as follows:

Cap	10–100	K–$\frac{1}{3}$	Factor 1200
Cap.	20–100	K–$\frac{2}{3}$	Factor 2400
Cap.	40–100	K–$1\frac{1}{3}$	Factor 4800
Cap.	100–100	K–$3\frac{1}{3}$	Factor 12000
Cap.	200–100	K–$6\frac{2}{3}$	Factor 24000

Ampere Hour Meters (Westinghouse)

Note the number of revolutions made by the "tell-tale" index on the top of the movement, in a number of seconds equal to the constant of the meter. The number of revolutions noted will correspond to the number of amperes passing through the meter. For example; the 20 ampere meter constant is 63.3; if the index makes ten revolutions in 63.3 seconds, ten amperes are passing through the meter. In order to avoid errors in reading, it is customary to take the number of revolutions in, say 120 seconds, then we get:

$$\frac{\text{Number of revolutions} \times \text{meter constant}}{\text{Number of seconds}} = \text{Current.}$$

If, therefore, the index of a 20-ampere meter makes 19 revolutions in 120 seconds, the current passing is

$$\frac{19 \times 63.3}{120} = 10 \text{ amperes.}$$

The constants of the different meters are:

Capacity,	K
5 amperes,	22.5
10 "	33.8
20 "	63.3
40 "	126.6
80 "	252.1
120 "	386
160 "	506
200 "	623

INSTRUCTIONS FOR TESTING LAMP HOUR METERS (DUNCAN). On account of the difference in the amount of current consumed by the various makes of lamps now upon the market, and the resulting difficulty of standardizing the meter so it will read with equal accuracy upon all lamps, adopt as standards of current 1.06 amperes for a 16 c. p., 50 volt lamp, and .55 amperes per 16 c. p , 100 volt lamp; these being respectively the average currents consumed by the majority of 50 and 100 volt lamps now in use.

If, however, the lamps which you are using, require a smaller current per 16 c. p. lamp than the above, the indications or readings of the meter will be slow, in which case the speed should be re-adjusted to suit these conditions. If the lamps take more current than is specified, the indication or reading will be fast. In testing a meter it is customary to load it with a certain number of lamps, then run it for a certain time and note the reading. This method is somewhat tedious and requires the expenditure of considerable energy, but there is no alternative in cases where the initial speed or revolutions per minute per lamp is not known.

The following method of testing will be found to be more accurate and economical, and one requiring less time for the operation.

It is necessary that the respective speeds "per lamp minute" for the different sizes of meters be known

before making this test. The speeds are as follows:

5 light	meters,	30 revolutions	per	minute	per lamp.
10 and 15	"	"	15	"	"	"
20, 25 and 30	"	"	10	"	"	"
40, 50 and 60	"	"	5	"	"	"
80, 100 and 120	"	"	2½	"	"	"
140, 160 and 200	"	"	1¼	"	"	"

With the foregoing data it is only necessary to turn on any number of lamps desired and count the number of revolutions per minute, which should, in each case, be equal to the initial or lamp minute speed of that size of meter multiplied by the number of lamps being tested.

Take, for example, a 10 light meter, and upon referring to the aforementioned data, we find that its speed "per lamp per minute," is 15 revolutions; therefore, if three lamps are turned on, the speed should be equal to 15 revolutions multiplied by three, or 45 revolutions per minute. If six lamps are turned on it should make 15× 6 or 90 revolutions per minute, and with 12 lamps the speed should be 15×12 or 180 revolutions per minute. Taking a 25 light meter its speed "per lamp per minute" is 10, and should revolve at a speed upon any load equal to the number of 16 c. p. lamps multiplied by 10. If it is found to be either fast or slow, it should be altered by adjusting the meter.

In making this test the cover must be kept on the meter, as the speed will be greatly reduced by the fans having to displace much more air when the cover is off. To further facilitate testing, any load or number of lamps may be used, as the meter follows a perfectly straight line law, thereby avoiding the necessity of testing with a different number of lamps in order to obtain the characteristic of the meter

The following table of loads will be found useful in testing the respective sizes, since the resulting speeds will not be too high or difficult to count by the untrained eye:—

Capacity in Lamp.	No. of Test Lamps.	Rev. per Min. per Lamp.	Total Rev. per Min.
5	3	30	90
10, 15	6	15	90
20, 25, 30	10	10	100
40, 50, 60	20	5	100
80, 100, 120	40	2½	100
140, 160, 200	80	1¼	100

EQUIVALENT METER RATES.

When ampere hour meters are used on 50 volt circuits, the rate at one cent per ampere hour is about the same as one cent per lamp hour, since 50-volt lamps (16 c. p.) take approximately one ampere each. But when employed on 100-volt circuits, the reading of the meter (in ampere hours) would be only one-half of what it would be in lamp hours, because 100-volt lamps (16 c p.) average half an ampere each: therefore, the price on an ampere hour basis must be doubled for 100-volt circuits.

If the foregoing does not meet with approval, and in order that the rate of charge may be the same on any voltage, the reading in ampere hours can be multiplied by the voltage of the circuit, which gives the watt hours: this at so much per 1000 watt hours will be the amount of the bill. For example: Suppose a meter operating on a 50-volt circuit, registers 386 ampere hours, the amount at one cent per ampere hour would be $3,86, and if on a watt hour basis it would be 386×50=19,300 watt hours: this at 20 cents per 1000 would be $3 86 If this same meter was operated for the same number of hours, and on the same number of 100-volt lamps, it would read 193 ampere hours, since the 100-volt lamps take only half an ampere each; this, however, at two cents per ampere hour (rate on 100-volt circuits) will be $3.86, and on a watt hour basis will be 190×100=19 300 watt hours, which at 20 cents per 1000 would be $3.86

The following equivalent charges will be found useful in computing the cost of lighting:

Lamp Meter 50 and 100 volts	Ampere Meter 50 volts	Ampere Meter 100 volts	Watt Meter 50 and 100 volts
$.0200	$.0200	$.0400	$.400
.0150	.0150	.0300	.300
.0100	.0100	.0200	.200
.0090	.0090	.0180	.180
.0080	.0080	.0160	.160
0075	.0075	0150	.150
.0070	.0070	.0140	.140
.0060	.0060	.0120	.120
.0050	.0050	0100	.100

A DISCOUNT INDICATOR is a maximum recording ampere meter for either direct or alternating currents, and records the maximum amperes that have passed through it at any one time since it was last set. A liquid is hermetically sealed in a glass tube, fitted with a heating bulb, around which the wire or heating strip pass. The passage of the current heats the air in one bulb and the expansion of the air forces the liquid into another bulb and indicating tube.

The liquid when once spilled over into the indicating tube cannot return until the meter is reset It is the difference in temperature between the two bulbs that works the meter. This meter is of value in determining rates.

READING METERS.

Read from right to left and see that each dial is checked by the adjoining dial to the right. On any dial the right hand one must complete the revolution before the adjacent left hand one can complete its corresponding division.

Note from book, last reading; from present reading deduct last reading, multiply the difference by constant of meter. Note if meter is watt hour meter, lamp hour, or ampere hour meter.

The same (above) rule applies to all.

To correct ampere hours to watt hours:

Ampere hours × average voltage of line = watt hours.

Watt hours $\div$ average voltage of line $=$ ampere hours.

Lamp hours $\times$ average consumption of lamp in watts $=$ watt hours.

Computing meter reading.

Ampere meters record only time and quantity.

Watt meters record time, quantity and pressure.

The rate of charge is based on the 16 c. p., lamp hour, (or approximately the 54 watt lamp hour.)

1 ampere, one hour $=$ 1-16 c p. lamp hour at 52 volts.

$\frac{1}{2}$ ampere, one hour $=$ 1-16 c. p. lamp hour at 104 volts.

If a meter (ampere) has a K for use on 50 volts, it should be doubled in all cases if used on 100 volts.

Arc light meters (watt) or any watt meter, to read in lamp hours, divide actual reading in watts by average consumption of lamp in watts.

To read watt hours in kilo watt hours, simply point off three places to the left. Thus, 4500 watt hours $=$ 4.5 K. W. hours.

Reading $\times$ K $\times$ rate $=$ Amount.

1000 watt hours $=$ 1 K. W. Hour.

746 watt hours $=$ 1 H. P. Hour.

Watt hours $\div$ 746 $=$ H. P. Hours.

$$\frac{\text{K. W. hour rate}}{1000} \times 746 = \text{Rate per H. P. hour.}$$

$$\frac{\text{H. P hour rate}}{746} \times 1000 = \text{Rate per K. W. hour.}$$

Short method for calculating.

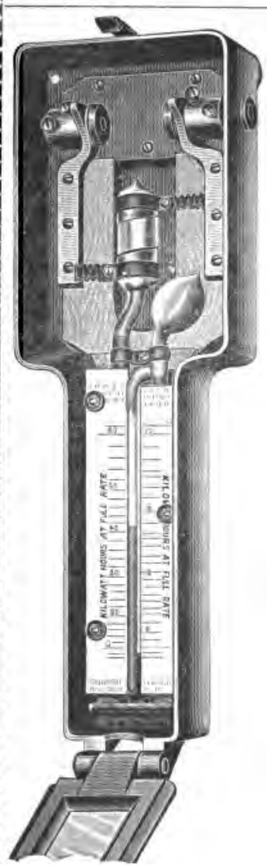
Rate $\times$ K of meter $=$ Calculating K.

Calculating K $\times$ direct reading $=$ Amount.

$$\frac{\text{Rate per K. W. hour}}{1000} \times \text{watt con. of lamp} = \text{rate pr lamp hr.}$$

$$\frac{\text{Rate per lamp hour}}{\text{Watt con. of lamp}} \times 1000 = \text{Rate per K. W. hour.}$$

INSTALLING METERS. Meters should be so installed as to be free from excessive heat or cold. They should be kept free from vibration For lighting only, fuses should be placed on service side and switch should be on load side of meter. For motor purposes, meter should be fused on both sides and the switch should be on the load side. This arrangement will prevent any "kick" from motor fields passing through and breaking down the potential path of meter.


KILOWATT HOURS AT FULL RATE

MEMORANDUM.

MEMORANDUM.

MEMORANUDM.

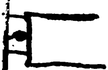
MEMORANDUM.

Mr. FERRIS has in preparation a book which he will call "System or Daily Tabulation about an Electric Light Plant."

This Book will sell for $1.00, and will show how it is EASIER to account for every item of expense than NOT TO DO SO.

By the methods taught, the amount of book-keeping necessary for the average plant will be about 20 hours for each month. Daily itemized accounts and reports are kept without books.

Figure 4



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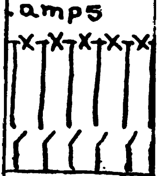

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